COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

HEARING CHARTER

Reviewing the Hydrogen Fuel and FreedomCAR Initiatives

Wednesday, March 3, 2004
2:00 – 4:00 p.m.
2318 Rayburn House Office Building

1. Purpose

On Wednesday, March 3, 2004, the U.S. House of Representatives' Committee on Science will hold a hearing to examine the Department of Energy's (DOE) Hydrogen Fuel and FreedomCAR initiatives. Specifically, the hearing will focus on two recent reports from the National Academy of Sciences (NAS) and the American Physical Society (APS) on DOE's hydrogen initiatives, and the Administration's response to the recommendations from the reports. The hydrogen program is one of the President's primary energy initiatives, and the two reports recommend changes to the program.

2. Witnesses

- **Mr. David Garman** is the Assistant Secretary of Energy Efficiency and Renewable Energy at the Department of Energy. Prior to joining the Department, Mr. Garman served as Chief of Staff to Alaska Senator Frank Murkowski and has served on the professional staff of the Senate Energy and Natural Resources Committee and the Senate Select Committee on Intelligence.
- **Dr. Michael Ramage** is the Chair of the National Academy of Sciences' (NAS), Committee on Alternatives and Strategies for Future Hydrogen Production and Use. Dr. Ramage is a retired executive vice president at ExxonMobil Research and Engineering Company.
- **Dr. Peter Eisenberger** is the Chair of the American Physical Society's (APS) Panel on Public Affairs Energy Subcommittee. Dr. Eisenberger is currently a Professor of Earth and Environmental Sciences at Columbia University, and has extensive academic and corporate research experience at Harvard, Stanford, Princeton, Exxon, and Bell Laboratories.

3. Overarching Questions

The hearing will address the following overarching questions:

- Are the Hydrogen Fuel and FreedomCAR initiatives on track to provide a viable alternative to petroleum as a transportation fuel?
- Are the goals of the Hydrogen Fuel and FreedomCAR initiatives appropriate and realistic? Are the initiatives designed to meet their goals?

- What are the most important recommendations from the NAS and APS reports? How is the Department responding to the recommendations?
- Will technology research alone lead to a transition to hydrogen, or will it be necessary to apply policy tools? How should a research and development effort take these policy choices into account?

4. Overview

- In his 2003 State of the Union speech, President Bush announced the creation of a new Hydrogen Fuel Initiative, which built on the FreedomCAR initiative announced in 2002. Together, the initiatives aim to provide the technology for a hydrogen-based transportation economy, including production of hydrogen, transportation and distribution of hydrogen, and the vehicles that will use the hydrogen. Fuel cell cars running on hydrogen would emit only water vapor and, if domestic energy sources were used, would not be dependent on foreign fuels.
- The recent reports from the American Physical Society (APS) and the National Academy of Sciences (NAS) both recommend changes to the hydrogen initiatives, particularly arguing for a greater emphasis on basic, exploratory research because of the significant, perhaps insurmountable, technical barriers that must be overcome. The APS report strongly cautions DOE against premature demonstration projects, saying such projects could repeat the government's unhappy experience with the synthetic fuels programs of the 1970s.
- The NAS study describes DOE's near-term milestones for fuel cell vehicles as "unrealistically aggressive." Both reports note that it will require technical breakthroughs – not just incremental improvements – to meet the goals of the overall hydrogen initiative. For example, the APS study states, "No material exists today that can be used to construct a hydrogen fuel tank that can meet the consumer benchmarks."
- The NAS study finds that in the DOE hydrogen program plan, the "priorities are unclear." The NAS study calls for "increased emphasis" on fuel cell vehicle development, distributed hydrogen generation, infrastructure analysis, carbon sequestration and carbon dioxide-free energy technologies.
- The NAS report notes that DOE needs to think about policy questions as it develops its research and development (R&D) agenda: "Significant industry investments in advance of market forces will not be made unless government creates a business environment that reflects societal priorities with respect to greenhouse gas emissions and oil imports…. The DOE should estimate what levels of investment over time are required – and in which program and project areas – in order to achieve a significant reduction in carbon dioxide emissions from passenger vehicles by mid-century."
- While the President's fiscal year 2005 (FY05) budget request includes additional funding for hydrogen R&D, it provides the money for hydrogen research by making cuts in other energy efficiency and renewable energy R&D programs. The APS report specifically argues against such an approach, and the NAS report notes that research on other aspects of renewable energy may be necessary for a successful transition to a hydrogen economy.

- The APS report recommends that DOE continue research into bridge technologies – such as gasoline or diesel hybrids and hydrogen-fueled internal combustion engines – that could provide benefits if the commercialization of fuel cell vehicles is delayed.

5. Background

Report Recommendations

NAS report recommendations summary

The NAS report raises “four pivotal questions” about the transition to a hydrogen economy:

- When will vehicular fuel cells achieve the durability, efficiency, cost, and performance needed to gain a meaningful share of the automotive market? The future demand for hydrogen depends on the answer.
- Can carbon be captured and sequestered in a manner that provides adequate environmental protection but allows hydrogen to remain cost-competitive? The entire future of carbonaceous fuels in a hydrogen economy may depend on the answer.
- Can vehicular hydrogen storage systems be developed that offer cost and safety equivalent to that of fuels in use today? The future of transportation use depends on the answer.
- Can an economic transition to an entirely new energy infrastructure, both the supply and the demand side, be achieved in the face of competition from the accustomed benefits of the current infrastructure? The future of the hydrogen economy depends on the answer.[1]

The report examines possible answers to the questions and recommends changes to the DOE hydrogen R&D program. The study concludes that, even under the most optimistic scenario, “[T]he impacts on oil imports and CO2 emissions are likely to be minor during the next 25 years.” The report goes on to add, “[T]hereafter, if R&D is successful and large investments are made in hydrogen and fuel cells, the impact on the U.S. energy system could be great.”

The report’s recommendations are summarized below.

Major NAS Recommendations:

- *Systems Analysis* – DOE should undertake more systems analysis to better understand the challenges, progress, and potential benefits of making the transition to a hydrogen economy.

[1] *The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs*. NAS pre-publication copy page 2-13.

- *Fuel Cell Vehicle Technology* – DOE should increase funding for fundamental research and development of fuel cells focusing on on-board storage systems, fuel cell costs, and durability.
- *Infrastructure* – DOE should provide "greater emphasis and support" to research, especially exploratory research, related to the creation of a hydrogen infrastructure. DOE should "create better linkages between its seemingly disconnected programs in large-scale and small-scale hydrogen production."
- *Infrastructure* – DOE should accelerate work on codes and standards, particularly addressing overlapping regulation at the municipal, state, and Federal levels.
- *Transition* – DOE should strengthen its policy analysis to better understand what government actions will be needed to bring about a hydrogen economy.
- *Transition* – DOE should increase investments in research and development related to distributed hydrogen production.
- *Safety* – DOE should make changes to hydrogen safety programs, including developing safety policy goals with stakeholders.
- *Carbon Dioxide-Free Hydrogen* – DOE should increase emphasis on electrolyzer development with a target of $125 per kilowatt with 70 percent efficiency. In parallel, DOE should set more aggressive electricity cost targets for unsubsidized nuclear and renewable energy that might be used to produce hydrogen.
- *Carbon Capture and Storage* – DOE should link its hydrogen programs more closely with its programs on carbon sequestration (which are managed by Fossil Energy).
- *RDD Plan* – DOE should set clearer priorities for hydrogen R&D and better integrate related programs spread among several DOE offices. Congress should stop earmarking funds for hydrogen R&D.
- *RDD Plan* – DOE should shift work away from development and toward exploratory work and should establish interdisciplinary energy research centers at universities.
- *Framework*– DOE should give greater emphasis to fuel cell vehicle development, distributed hydrogen generation, infrastructure analysis, carbon sequestration and FutureGen, and carbon dioxide-free energy technologies.

APS report recommendations summary

The APS recommendations are generally consistent with those of NAS. The primary recommendation of the APS report is that DOE should significantly increase the funding for basic research in the hydrogen initiative, while reducing the funding for demonstrations. The report outlines the various technical barriers facing each stage of hydrogen usage, and the fundamental research breakthroughs that are needed to make the initiative a success. APS concludes that large-scale demonstrations are generally premature because so many technological hurdles still must be cleared.

The APS report also recommends that the Administration increase funding for "bridge" technologies – such as hydrogen internal combustion engines and gasoline and diesel hybrid vehicles – that would provide benefits sooner than hydrogen fuel cell vehicles, particularly if technical barriers slow the market penetration of the fuel cell vehicles. The APS report also argues that the hydrogen initiatives should not displace other efficiency and renewable energy research if the goals of the initiative are to be met. Renewable energy generation, APS argues, is crucial to supplying clean, domestic energy for hydrogen production.

Challenges

What are the technical challenges?

Major advances are needed across a wide range of technologies if hydrogen is to be affordable, safe, cleanly produced, and readily distributed. The production, storage and use of hydrogen all present significant challenges.

Hydrogen can be produced from a variety of sources, including coal and natural gas. But one goal of using hydrogen is to reduce emissions of carbon dioxide. If hydrogen is to be produced without emissions of carbon dioxide, then the technology to capture and store carbon dioxide (known as carbon sequestration) must improve significantly. The other main goal of using hydrogen is to reduce the use of imported energy. Today most hydrogen is produced from natural gas, but in order to supply the entire transportation sector significant imports of natural gas would be required. Other possible means of producing hydrogen are inherently cleaner than coal, but are far from affordable with existing technology. For example, the APS estimates that hydrogen produced through electrolysis is currently four to ten times more expensive than gasoline.

Another major hurdle is finding ways to store hydrogen, particularly on board a vehicle. APS believes "a new material must be discovered" to develop an affordable hydrogen fuel tank.

The NAS estimates that fuel cells themselves will need a ten- to twenty-fold improvement before fuel cell vehicles become competitive with conventional technology. Today's fuel cells also wear out quickly, and are therefore far short of the durability that would be required to compete with a gasoline engine. Finally, if hydrogen is going to be produced on a large-scale, dramatic improvements in pipeline and tanker technology are required to permit the efficient and safe transportation and distribution of hydrogen. Small-scale distributed production also needs improvement, and the NAS report recommends increased focus in that area because it may be the first to develop.

What are the non-technical challenges? (policy, regulatory, inertia, public awareness)

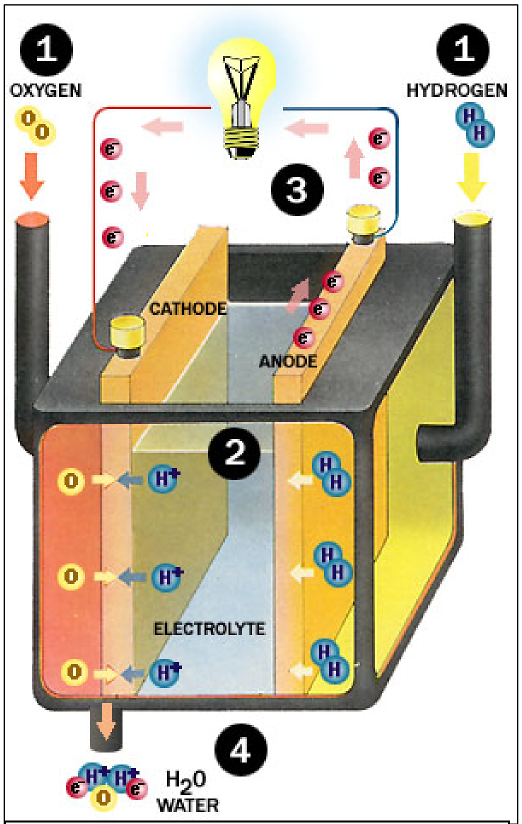
Even if the technology advances to a point at which it is competitive, the transition to a hydrogen economy will require an enormous investment to create a new infrastructure. Changes in regulation, training and public habits and attitudes will also be necessary. Estimates of the cost of creating a fueling infrastructure (replacing or altering gas stations) alone are in the hundreds of billions of dollars.

The transition also won't happen quickly. According to the NAS study, significant sales of hydrogen vehicles are unlikely before 2025 even under the most optimistic technology assumptions.

Technology

What is a Fuel Cell?

Central to the operation of the hydrogen-based economy is a device known as a fuel cell that would convert hydrogen fuels to electricity. In cars, these devices would be connected to electric motors that would provide the power now supplied by gasoline engines. A fuel cell produces electricity by means of an electrochemical reaction much like a battery. However, there is an important difference. Rather than using up the chemicals inside the cells, a fuel cell uses hydrogen fuel, and oxygen extracted from the air, to produce electricity. As long as hydrogen fuel and oxygen are fed into the fuel cell, it will continue to generate electric power.



1. Hydrogen gas is extracted from natural gas or other sources and permeates the anode. Oxygen from the air permeates the cathode.
2. Aided by a catalyst in the anode, electrons are stripped from the hydrogen. Hydrogen ions pass into the electrolyte.
3. Electrons cannot enter the electrolyte. They travel through an external circuit, producing electricity.
4. Electrons travel back to the cathode where they combine with hydrogen ions and oxygen to form water.

Source - DOE

Different types of fuel cells work with different electrochemical reactions. Currently most automakers are considering Proton Exchange Membrane (PEM) fuel cells for their vehicles.

Benefits of a Hydrogen-based Economy

A hydrogen-based economy could have two important benefits. First, hydrogen can be manufactured from a variety of sources, including natural gas, biofuels, petroleum, coal, and even by passing electricity through water (electrolysis). Depending on the choice of source, hydrogen could substantially reduce our dependence on foreign oil and natural gas.

Second, the consumption of hydrogen through fuel cells yields water as its only emission. Other considerations, such as the by-products of the hydrogen production process, will also be important in choosing the source of the hydrogen. For example, natural gas is the current feedstock for industrial hydrogen, but its production releases carbon dioxide; production from coal releases more carbon dioxide and other emissions; and production from water means that pollution may be created by the generation of electricity used in electrolysis. Production from solar electricity would mean no pollution in the generation process or in consumption, but is currently more expensive and less efficient than other methods.

Table 1. Current Federal Activities

Hydrogen Initiatives Budget ($ million)					
Department/Office	**2003 Actual***	**2004 Enacted****	**2005 Request**	**Dollar Change, 2004 to 2005**	**Percent Change, 2004 to 2005**
Energy / EERE Hydrogen Fuel	92	147	173	26	17
Energy / EERE FreedomCAR	152	155	169	14	9
Energy / Fossil Energy (coal)	2	5	16	11	227
Energy / Nuclear Energy	2	6	9	3	41
Energy / Basic Energy Sciences	0***	0***	29	29	-
Department of Transportation	0	0.6	0.8	0.3	50
TOTAL ******	**180**	**249**	**319**	**71**	**28**

* Reflects funding for baseline activities that the Hydrogen Fuel Initiative (HFI) augments and/or redirects. 2004 was the first year for the HFI, 2003 was the first year for FreedomCAR.
** Reflects rescissions, general reductions, and other adjustments included in relevant 2004 appropriations.
*** Base funding for hydrogen-related activities in Basic Energy Sciences was roughly $8 million in 2003 and 2004. These activities have been reoriented and expanded to support the goals of the President's HFI in 2005.
**** Columns do not add due to FreedomCAR and HFI funding overlaps and rounding.

Industry participation

Although exact numbers on industry involvement are proprietary, the major automobile companies have invested billions of dollars in R&D and demonstrations of fuel cell vehicles. General Motors alone had spent $1 billion as of June 2003, and estimated that its total investment by 2010 could triple.

Legislation

Language in the portion of the comprehensive Energy Bill (H.R. 6) produced by the Science Committee would authorize and guide the hydrogen initiative. The conference report on H.R. 6 is still pending in the Senate.

6. Questions to the Witnesses

The witnesses have been asked to address the National Academy of Sciences' (NAS) and American Physical Society's (APS) recent reports and recommendations on the hydrogen initiatives in their testimony, and in addition the following specific questions.

Mr. David Garman:

1. The NAS report describes the goals of the initiatives as "unrealistically aggressive" while the APS report highlights the significant "performance gaps" between current technology and the initiative milestones. Does the Department of Energy (DOE) plan to adjust the goals based on the comments of these reports? If not, how does DOE plan to respond?

2. Because of the significant technical challenges, both reports criticized the current mix of funding for hydrogen research, arguing that more emphasis should be placed on fundamental research as opposed to demonstrations. Please describe the hydrogen program's current demonstration and deployment efforts, and how each technology element's current costs and performance measure against the program goals. Does DOE plan to adjust the balance of funding to match the recommendations? If not, why?

3. The NAS report suggests that the research agenda should be developed with future policy decisions in mind. How did the Administration consider the impact of future policy decisions in the development of the research agenda for the hydrogen initiatives? Does DOE plan on increasing its policy analysis capabilities as recommended by the NAS?

4. What are the key criteria for deciding that a technology is ready for demonstration? Are there guidelines or rules of thumb, such as 120 percent of cost goals, or 85 percent of performance goals that indicate that a technology is ready for demonstration-scale activities?

5. Using the definitions in OMB Circular A-11, what is the proposed mix of funding in the FY05 budget request between basic research, applied research, development, demonstration, and deployment activities within the Hydrogen Fuel Initiative?

Dr. Michael Ramage:

1. Given the current state of hydrogen technology, what do you feel the federal funding balance should be between demonstration and research?

2. One of the recommendations included in the NAS report calls for an expanded policy analysis program at the Department of Energy. Please describe why the committee felt this was important, and give more detail as to what such a program might encompass.

3. In the penetration models included in the NAS study, the committee assumes that the technical goals will be met, even though they are deemed overly optimistic. What would be more realistic goals? How would that affect the penetration models? What would that imply for the delivery of public benefits such as environmental improvements and reduced oil dependence?

4. What are the key criteria for deciding that a technology is ready for demonstration? Are there guidelines or rules of thumb, such as reaching 120 percent of cost goals, or 85 percent of performance goals, that indicate that a technology is ready for demonstration-scale activities?

5. While the NAS report recommends shifting funding away from "bridge" technologies such as gasoline and diesel hybrids and hydrogen internal combustion engines, another recently released report from the American Physical Society (APS) encourages DOE to increase funding in these areas in light of their near term benefits. How would you respond to the APS recommendation? What do you feel is the reason for the different opinions about Federal investment in bridge technologies?

Dr. Peter Eisenberger:

1. One of the major themes of the APS report is the lack of funding for basic research. The report notes that the Department's request of $29 million in the Office of Science for fiscal year 2005 was a dramatic improvement, but says that the amount of basic research is still inadequate at 13 percent of the overall hydrogen funding. What do you feel the balance should be? How should it change over time?

2. What are the key criteria for deciding that a technology is ready for demonstration? Are there guidelines or rules of thumb, such as reaching 120 percent of cost goals, or 85 percent of performance goals, that indicate that a technology is ready for demonstration-scale activities?

3. While the APS report encourages DOE to increase funding to "bridge" technologies such as gasoline and diesel hybrids and hydrogen internal combustion engines, another recently released report from the National Academy of Sciences (NAS) recommends shifting funds away from bridge technologies. How would you respond to the NAS recommendation? What do you feel is the reason for the different opinions about Federal investment in bridge technologies?